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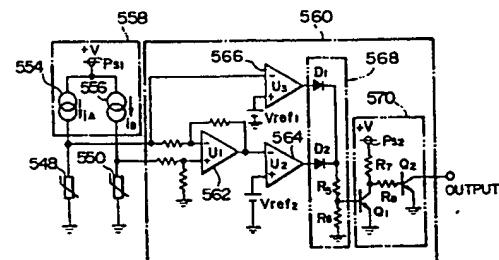
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**54 Frost and dew sensor.**

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⑤ In a frost and dew sensor composed of two thermosensitive resistors, a power source and an arithmetic circuit, frost or dew is detected from the change of a differential temperature between the two thermosensitive resistors as two different currents from the power source are supplied to the respective thermosensitive resistors. In an alternative form, the sensor has a single thermosensitive resistor, which is energized as two different currents are alternately supplied from the power source so that frost or dew is detected by comparison of the time-lags between the two outputs from the thermosensitive resistor.

FIG. 2



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## FROST AND DEW SENSOR

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention:

This invention relates to a frost and dew sensor for use in a defroster of a refrigerator, air-conditioner and various other industrial appliances.

## 2. Description of the Related Art:

It has been a common knowledge that under certain conditions, the surface of a heat-exchanger, incorporated in a refrigerator, an air-conditioner or a similar apparatus, is covered with frost and ice. Continued operation of the heat-exchanger covered with frost and ice would remarkably reduce the energy efficiency, which is uneconomical and occasionally causes a failure or fault.

Heretofore, attempts were made to detect the building-up of frost and dew; some of the proposed detecting means used a resonator, some utilized the change of dielectric constant of an element due to the developing of frost or dew, and others were optical type.

FIGS. 13 through 16 of the accompanying drawings illustrate two prior art sensors each using a resonator; one sensor detects the change of resonance frequency of a resonator, and the other detects the change of amplitude of a resonator.

In FIG. 13, a piezo-electric resonator 14 is supported on the upper surface of a tubular housing 10 via a resilient support 12 and bears a pair of electrodes 16a, 16b attached one on each side of the resonator 14, and a pair of output terminals 18a, 18b leading from the electrodes 16a, 16b, respectively.

FIG. 14 is a circuit diagram of the sensor of FIG. 13, in which the output of the resonator 14 is supplied to a resonance-frequency discriminator 22 via a resistor R on one side and an amplifier 20 on the other side where the output is amplified as a matter of fact. Then the output of the discriminator 22 is taken out to the exterior. In operation, as frost or dew develops over the surface of the resonator 14, the resonance frequency derived from the resonator 14 varies depending on the amount of frost or dew built up. When the extent of change in resonance frequency climbs over a predetermined value, this sensor discriminates or judges that the resonator 14 has been covered with frost or dew.

The sensor of FIG. 15 is of the type in which the developing of frost or dew is detected based on the change of amplitude of a resonator 114. This

sensor is identical in basic construction with that of FIG. 13; but, the output of the resonator 114 is supplied to an oscillation amplitude discriminator 124, as shown in FIG. 16. In this sensor, as frost or dew develops over the surface of the resonator 114, the oscillation of the resonator 114 is restricted depending on the weight of frost or dew grown up. Thus when the extent of change in amplitude ascends beyond a predetermined value, this sensor presumes that the surface of the resonator 114 has been covered with frost or dew.

FIGS. 17 to 19 are diagrams showing various wave forms of the oscillation outputs of the piezo-electric resonator 114 and of the detected outputs of the sensors shown in FIGS. 13 through 16.

Specifically, FIG. 17 shows a wave form of the oscillation output of the sensor of FIGS. 13 and 14, indicating that at a time point  $t_1$ , concurrently with the developing of frost, the resonance frequency increased about two times. FIG. 18 shows another wave form of the oscillation output of the sensor of FIGS. 15 and 16; it can be observed that concurrently with the developing of frost or dew (time point  $t_1$ ), the amplitude of the output signal derived from the resonator 114 is reduced.

When any change of the oscillation frequency or amplitude has thus been found, the sensor outputs a signal giving a notice that the resonator 14, 114 has been covered with frost or dew, in response to which generally a defroster or a dehumidifier is energized.

FIGS. 20 to 22 illustrate another prior art sensor of the type utilizing the change of dielectric constant to detect frost and dew. FIGS. 20 and 21 show the inside structure and outside appearance, respectively, of the sensor; a resistor film 230 is coated over the surface of an insulating substrate 228 on which a pair of comb-shaped electrodes 226, 226 is printed. FIG. 22 shows a detector circuit of the sensor; an alternating voltage from an alternating signal source 134 is impressed to a detection unit 232 having the construction of FIGS. 20 and 21, and the output of the detection unit 232 is supplied to an impedance detector circuit 236, the output terminal of which is connected to a non-illustrated defroster or dehumidifier.

With this prior arrangement, as frost or dew develops over the surface of the detection unit 232, the alternating impedance between the two comb-shaped electrodes 226, 226 varies. When the impedance detector circuit 236 detects this change in the impedance, it presumes that the surface of the detection unit 232 has been covered with frost or dew.

FIGS. 23 and 24 illustrate an optical type of

prior art sensor.

Specifically, FIG. 23 shows the principle of operation of the sensor having a light-emitting element 338 and a light-receiving element 340; light from the light-emitting element 338 reflects on a reflection surface 342 and then strikes on the light-receiving element 340. As frost or dew develops over the reflection surface 342, the refractive index of the light from the light-emitting element 338 or the angle of incidence of the light falling on the light-receiving element 340 deviates so that the amount of light falling on the light-receiving element 340 is reduced. When any change of the light amount is thus found, the sensor makes a judgment that the surface of the reflection surface 342 has been covered with frost or dew.

FIG. 24 show the principle of operation of the sensor having an LED (light-emitting diode) 438 and a photodiode 440 receptive of the light from the LED 438. As frost or dew develops on a path of light spanning between the LED 438 and the photodiode 440, the amount of light to reach the photodiode varies. When the extent of change in the light amount is compared with a reference value in a level discriminator 444 and is thus found over the reference value, the level discriminator 444 issues a notice that the path of light between LED 438 and the photodiode 440 has been at least partly blocked by frost or dew grown up.

With the foregoing prior arrangement, the following problems are unavoidable so that adequate usefulness cannot be achieved.

Each of the known sensors of FIGS 13 through 16, in which a piezo-electric resonator is used, tends to operate incorrectly due to the dust or other foreign matter stuck to the resonator or due to vibrations exerted on the resonator interiorly and exteriorly of the sensor.

In the known sensors of FIGS. 20 through 24, some utilizing the change in dielectric constant and others adopting an optical method, partly since it is difficult to reduce the detection unit into a compact size, and partly since the circuit structure is too complex, maintenance on a periodical basis is essential to keep the detection precision at a pre-determined level. Accordingly, it is difficult not only to achieve reproducibility, but also to reduce the cost of production.

#### SUMMARY OF INVENTION

It is therefore an object of this invention to provide a frost and dew sensor which is compact in size and hence inexpensive to manufacture and which is excellent in both detection precision and reproducibility.

According to a first aspect of this invention,

there is provided a frost and dew sensor comprising: a pair of thermosensitive resistors disposed adjacent to each other, each of the thermosensitive resistors being capable of generating heat by itself due to a given current supplied thereto, each thermosensitive resistor having a resistance varying according to the change of temperature of each thermosensitive resistor; a power source for creating a differential temperature between the thermosensitive resistors, the power source including a heat-generating current source for supplying a heat-generating current to one of the thermosensitive resistors, and a comparative reference current source for supplying a comparative reference current to the other thermosensitive resistor so as to cause a temperature increase of the other thermosensitive resistor to only a negligible extent with respect to the temperature increase of the one thermosensitive resistor due to the heat-generating current; and an arithmetic circuit for fetching a temperature at a respective one of the thermosensitive resistors as an output voltage corresponding to the resistance of the respective thermosensitive resistor and for generating a frost-and-dew signal according to a difference in output voltage between the pair of thermosensitive resistors.

In this first arrangement, in air, one thermosensitive resistor receptive of a current supplied from a heat-generating current source is kept at a temperature higher than the temperature of the other thermosensitive resistor receptive of a current normally supplied from a comparative reference current source.

When frost or dew develops over the these two thermosensitive resistors located adjacent to each other, heat radiation, from the one thermosensitive resistor kept at a high temperature due to a relatively large current from the heat-generating current source, occurs via the frost or dew developed over the surface of that one thermosensitive resistor. This is because either solid (frost) or liquid (dew) has a heat conductivity larger than air, i.e., gas. As a result, the temperature of the one thermosensitive resistor descends to reduce a differential temperature with respect to the other thermosensitive resistor kept at a substantially constant temperature due to a current supplied from the comparative reference source.

The arithmetic circuit calculates the differential temperature created between the two thermosensitive resistors; when this differential temperature satisfies specified conditions, the arithmetic circuit makes a judgment that the surfaces of the thermosensitive resistors have been covered with frost or dew, and outputs a frost-and-dew signal.

The arithmetic circuit may include a comparator circuit which is composed of two comparators, for example. One of the comparators compares the

respective output signals of the thermosensitive resistors with one another, and the other comparator compares the output signal of the one comparator with a reference value.

Further, the arithmetic circuit may be equipped with a freezing level detector circuit for comparing the output of the other thermosensitive resistor corresponding to the comparative reference current with a predetermined freezing level reference value to detect only the developing of frost. The arithmetic circuit may also be equipped with a discriminator for comparing the output of the comparator circuit with the output of the freezing level detector circuit.

The frost-and-dew signal may be outputted through an output circuit where this signal is amplified. The sensor may use a shaft for carrying thereon the individual thermosensitive resistor, and a base supporting the shaft.

The arithmetic circuit should by no means be limited to the analog type. That is, in an alternative form, the output of the individual thermosensitive resistor may be converted between analog form and digital form by an A/D converter, then a differential temperature may be calculated by a  $\mu$ -CPU, and finally a frost-and-dew signal may be outputted based on the arithmetical result.

The individual thermosensitive resistor may be a thermistor or a resistor made from platinum or nickel.

According to a second aspect of this invention, there is provided a frost and dew sensor comprising: a thermosensitive resistor capable of generating heat by itself due to a given current supplied thereto, said thermosensitive resistor having a resistance varying according to the change of temperature of said thermosensitive resistor; a power source for changing the temperature of said thermosensitive resistor periodically, said power source including a variable constant-current source for alternately supplying a heat-generating current and a comparative reference current to said thermosensitive resistor, said comparative reference current being such that it causes a temperature increase of said thermosensitive resistor to only a negligible extent with respect to the temperature increase due to the heat-generating current; and an arithmetic circuit for fetching a temperature of said thermosensitive resistor as an output voltage according to a resistance corresponding to the temperature and for generating a frost-and-dew signal according to a difference between the output voltage during the heat-generating current is being supplied to said thermosensitive resistor and the output voltage during the comparative reference current is being supplied to said thermosensitive resistor.

In this second arrangement, the arithmetic circuit may include an amplifier for amplifying the

output voltage of said thermosensitive resistor, during the comparative reference current is being supplied thereto, a holding circuit for holding the output of said amplifier to output the same output with a delay for the duration the comparative reference current is being supplied to said thermosensitive resistor, and a comparator circuit for comparing a differential temperature, between the output of said holding circuit and the output voltage of said thermosensitive resistor during the heat-generating current is being supplied, with a predetermined reference value.

Further, the power source may be equipped with a timing circuit including an oscillator for producing an alternate timing to alternate the output of said variable constant-current source between the comparative reference current and the heat-generating current. Each of the amplifier and an output circuit similar to that of the first arrangement may be equipped with a switch adapted to be energized and deenergized by the timing circuit.

It is also particularly useful when additional parts similar to those of the first arrangement are incorporated in this second arrangement.

To sum up, according to this invention, since the developing of frost or dew is judged in terms of temperature, occurrence of any misdetection due to dust or other foreign matter stuck on the surface of a detection unit can be reduced to a minimum. Further, since at least one thermosensitive resistor, which is small in size and inexpensive, is used, it is possible to achieve a frost and dew sensor which can be manufactured at a reduced cost and can offer an improved performance.

The above and other objects, features and additional advantages of this invention will become manifest to those versed in the art upon making reference to the detailed description and the accompanying drawings in which a variety of preferred structural embodiments incorporating the principle of this invention are shown by way of illustrative example.

#### 45 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing a partial appearance of a frost and dew sensor according to a first embodiment of this invention, in which a pair of thermosensitive resistors is located adjacent to each other;

FIG. 2 is a circuit diagram of the sensor of the first embodiment;

FIG. 3 is a characteristic curve graph showing the general relation between the temperature and resistance of a thermosensitive resistor;

FIG. 4 is a characteristic curve graph showing the relation between the temperature or dif-

ferential temperature and the resistance when no frost or dew exists around the thermosensitive resistors in the first embodiment;

FIG. 5 is a characteristic curve graph similar to FIG. 4, showing the typical relation between the temperature or differential temperature and the resistance when frost or dew has developed over the thermosensitive resistors;

FIG. 6 is a block diagram of a modified sensor according to a second embodiment;

FIG. 7 is a block diagram of another modified sensor according to a third embodiment;

FIG. 8 is a perspective view showing a partial appearance of the sensor of the third embodiment;

FIG. 9 is a side elevational view of FIG. 8, showing the sensor with no frost or dew around;

FIG. 10 is a view similar to FIG. 9, showing the sensor having been covered with frost or dew;

FIG. 11 is a detail circuit diagram corresponding to FIG. 7;

FIG. 12 is a block diagram showing still another modified sensor according to a fourth embodiment;

FIG. 13 is a cross-sectional view of a prior art sensor for detecting frost or dew by the change in oscillation frequency of a piezo-electric resonator;

FIG. 14 is a circuit diagram of the sensor of FIG. 13;

FIG. 15 is a view similar to FIG. 13, showing another prior art sensor for detecting frost or dew by the change in oscillation amplitude of a piezo-electric resonator;

FIG. 16 is a circuit diagram of the sensor of FIG. 15;

FIG. 17 is a wave-form graph showing the oscillation output of the sensor of FIG. 13;

FIG. 18 is a wave-form graph similar to FIG. 17, showing the oscillation output of the sensor of FIG. 15;

FIG. 19 is a detection output graph corresponding to FIGS. 17 and 18, showing the presence/absence of frost or dew;

FIG. 20 is a plan view of still another prior art sensor in which frost or dew is detected in terms of the change in dielectric factor;

FIG. 21 is a perspective view of the sensor of FIG. 20;

FIG. 22 is a block diagram showing a circuit of the sensor of FIG. 20; and

FIGS. 23 and 24 are schematic diagrams of two other kinds of prior art sensors, showing the structure and the principle of operation of the individual sensor in which frost or dew is detected in terms of the change of amount of light reached a photodiode from an LED.

## DETAILED DESCRIPTION

Various preferred embodiments of this invention will now be described with reference to the accompanying drawings. A thermistor is used here as a thermosensitive resistor.

FIG. 1 shows a partial appearance of a frost and dew sensor (hereinafter also called "sensor") according to a first embodiment of this invention.

In the sensor of the first embodiment, the developing of frost or dew can be judged or discriminated in terms of a differential temperature created between a pair of thermosensitive resistors. In the illustrated example, the sensor comprises a pair of thermosensitive resistors 548, 550 disposed parallel to each other. These two thermosensitive resistors 548, 550 are carried on a pair of shafts 552a and 552b, or 552c and 552d, respectively, supported between opposite side walls of a base 546 with a constant distance between the shafts. In this embodiment, a thermistor having a resistance of 5 k $\Omega$  at a B constant of 3350 and 25°C is used for each of the thermosensitive resistors 548, 550. The heat radiation of the thermistor is 2 mW/°C in air and about 50 mW/°C in ice. Further, the thermistor offers a resistance of 14 k $\Omega$  at 0°C.

FIG. 2 shows the entire circuit of the sensor of this invention, in which the thermosensitive resistors 548, 550 are grounded at one end, and currents are supplied from a power source Ps to the thermosensitive resistors 548, 550 via a pair of constant-current variable circuit 554, 556, respectively, in which different output current values are preset.

These two constant-current variable circuits 554, 556 jointly constitutes a power source 558.

The thermosensitive resistors 548, 550 and the power source 558 are connected to an arithmetic circuit 560 which outputs a frost-and-dew signal in a manner described below.

The respective outputs of the constant-current variable circuits 554, 556 are supplied to an operational amplifier 562 where a differential temperature between the thermosensitive resistors 548, 550 is calculated. The calculated differential temperature is supplied to one input terminal of a comparator 564 where a judgment is made on whether the differential temperature is below a direct-current reference voltage Vref<sub>2</sub>.

Meanwhile, the comparator 566 monitors a temperature of the thermosensitive resistor 548 and compares the monitored temperature with a direct-current reference voltage Vref<sub>1</sub> to discriminate whether the monitored temperature is below a reference value.

By this comparison, it is possible to detect the developing of frost only, i.e., apart from the developing of dew, provided that the reference voltage

$V_{ref_1}$  is preset to a value equivalent to that at 0°C.

Each of the comparators 564, 566 issues an output only when either the differential temperature value or the monitored temperature value is below a reference value. In the illustrated example, this output is negative logic; a base current flows to a transistor  $Q_2$  to render the transistor conductive only when these two outputs meet, the transistor  $Q_2$  being included in an output circuit 570.

A transistor  $Q_1$  is deenergized only when the two outputs meet. At that time a voltage is impressed from a power source  $P_{S2}$  to the transistor  $Q_2$  via resistances  $R_7, R_8$  to energize the transistor  $Q_2$ . As thus energized, the transistor  $Q_2$  outputs an open collector signal giving a notice of the developing of frost or dew.

The operation of the sensor according to the first embodiment will now be described.

In general, a thermosensitive resistor has a temperature-resistance characteristic such as shown in FIG. 3; temperature and resistance are virtually in reverse proportion to each other.

In FIG. 2, to the one thermosensitive resistor 548, a feeble direct current (i.e., comparative reference current)  $i_A$ , such that a temperature increase due to the self-heat-generation is negligible, is supplied from a power source  $P_{S1}$  via the constant-current variable circuit 554. To the other thermosensitive resistor 550, another direct current (i.e., heat-generating current)  $i_B$ , such that a temperature increase is constant, is supplied from the common power source via the constant-current variable circuit 556. In this case, assuming that the temperature increase of the thermosensitive resistor 550 is  $\Delta T$ , this  $\Delta T$  is determined from an amount of electric power consumed by the thermosensitive resistor 550 and an amount of heat energy ( $Q_r$ ) radiated from the same thermosensitive resistor.

The relation between an ambient temperature and a thermosensitive resistor temperature and the relation between an ambient temperature and a differential temperature of the thermosensitive resistors 548, 550, when the thermosensitive resistors 548, 550 are in air, namely, when no frost or dew exists around the thermosensitive resistors 548, 550, are shown in FIG. 4.

It is a common knowledge that the amount of heat radiation of a thermosensitive resistor varies sharply depending on whether the thermosensitive resistor is disposed in gas or it is disposed in solid or liquid. This is because the heat conductivity of solid is larger by two figures, compared with that of gas.

Now if the respective temperatures of the two thermosensitive resistors 548, 550 are compared to one another in air, the temperature of the one thermosensitive resistor 548 is  $T_0 + \Delta T_a$ , and the temperature of the other thermosensitive resistor

550 is  $T_0 + \Delta T_b$ . Therefore the differential temperature is  $\Delta T_b - \Delta T_a$ . Here  $T_0$  stands for air temperature.

On the other hand, if the two thermosensitive resistors 548, 550 are located in water or ice (frost), their respective temperatures are  $T_1' + \Delta T_a'$  and  $T_1' + \Delta T_b'$ . Therefore the differential temperature is  $\Delta T_b' - \Delta T_a'$ .

However, because the heat conductivity of water or ice is larger than that of air,  $\Delta T_a' \ll \Delta T_a$  and  $\Delta T_b' \ll \Delta T_b$ . As a result, as shown in FIG. 5, the temperature  $\Delta T_b' - \Delta T_a'$  is large enough, compared to  $\Delta T_b - \Delta T_a$ .

When the differential temperature between the two thermosensitive resistors 548, 550 is reduced to more than a predetermined extent, it can be regarded as a sign that the surfaces of thermosensitive resistors 548, 550 have been covered with frost or dew.

20 In FIG. 2, the operational amplifier 562 detects the respective temperatures of the two thermosensitive resistors 548, 550 to obtain a difference therebetween and then supplies this differential temperature value to one input terminal of the comparator 564.

25 To the other input terminal of the comparator 564, a reference voltage  $V_{ref_2}$ , equivalent to the differential temperature between the two thermosensitive resistors 548, 550 when no frost or dew exists around the thermosensitive resistors 548, 550, is impressed. The comparator 564 thus makes a discrimination as to whether the output of the operational amplifier 562 is below the reference voltage value  $V_{ref_2}$ .

30 According to the principles of this invention, yet when the surface of a thermosensitive resistor is covered with water (dew) instead of ice (frost),  $\Delta T_b - \Delta T_a$  is small. Therefore, for detecting frost and dew distinctly of each other, a comparator 566 may be used to monitor an ambient temperature  $T_0$  via the one thermosensitive resistor 548 which is at a temperature very close to the ambient temperature  $T_0$  because the amount of current supplied to the thermosensitive resistor 564 is very small.

35 To the other input terminal of the comparator 566, a reference voltage  $V_{ref_1}$ , equivalent to the freezing point of water is impressed from the direct-current source. When this input signal indicative of the monitored temperature from the thermosensitive resistor 548 is smaller than a reference voltage signal, it can be regarded as a sign that the surface of the thermosensitive resistor 548 has been covered with frost, not water.

40 When the detection signal of either comparator 564, 566 is below the reference value, a negative logic output is issued to take a logical operation AND by a pair of diodes  $D_1, D_2$  which jointly

constitutes a discriminator 568.

Only when the outputs of the two comparators 564, 566 meet, the transistor  $Q_1$  is deenergized to stop the current flow from the power source  $P_{S2}$  to the ground.

Consequently a voltage is impressed to the base of the transistor  $Q_2$  from the power source  $P_{S2}$  via the resistances  $R_7$ ,  $R_8$ , and the transistor  $Q_2$  is thereby energized to issue to a non-illustrated defroster drive unit, for example, an output signal giving a notice of the developing of frost. This output means: "the ambient temperature (i.e., temperature of the thermistor 12) is below 0 °C, and the surfaces of the thermosensitive resistors are covered with ice (frost)".

The differential temperature  $\Delta T_b - \Delta T_a$  varies depending on the state of ice covering over the thermosensitive resistors; by selectively varying the reference voltage of the comparator 564, it is possible to detect the developing of ice (frost) with maximum sensitivity.

If it is not necessary to distinguish between frost and dew when detecting, the comparator 566 and the diodes  $D_1$ ,  $D_2$  may be omitted.

In the foregoing embodiments, a thermistor is used for each thermosensitive resistor. However, this invention should by no means be limited to this specific form. The thermosensitive resistor may be a resistor made from platinum or nickel, for example, provided that the resistance-temperature coefficient of that resistor is positive.

Further, a control circuit employing a timer circuit or a microcomputer may be added in the arithmetic circuit.

In the illustrated embodiments, the arithmetic circuit is composed of a single operational amplifier, a pair of comparators, and transistors. Alternatively, the output voltage of the thermosensitive resistor may be inputted to an A/D converter and then may be processed as digital data with arithmetic operations by a microprocessor.

FIG. 6 is a block diagram showing a second embodiment having such an alternative construction. In this embodiment, a modified arithmetic circuit 660 is composed of an A/D converter 672 for converting the output currents of two thermosensitive resistors 648, 650 from analog form to digital form, a  $\mu$ -CPU 674 for calculating a differential temperature between the thermosensitive resistors 648, 650 from digital data outputted from the A/D converter 672, and an output circuit 670 for outputting a frost-and-dew signal based on the output of the  $\mu$ -CPU 674. The arrangement of this embodiment can offer the same result as that of the first embodiment.

FIG. 7 shows a third embodiment, in which two different-value currents i.e., a heat-generating current and a comparative reference current from a

constant-current variable circuit 776 are alternately supplied to a single thermosensitive resistor 750 grounded at one end.

In the third embodiment, time-divided different currents  $i_A$ ,  $i_B$  are supplied to the single thermosensitive resistor 750, and the differential temperature is detected in terms of the different amounts of heat energy radiated when frost or dew exists around and when no frost or dew exists around.

5 This detection is achieved by temporarily delaying one of the two output voltage values of the thermosensitive resistor 750 to meet with the detection timing signal of the other output voltage value for comparison.

10 Specifically, one of two alternately selective detection values is delayed and then supplied to the comparator circuit 762 at the same timing as the succeeding other detection value.

15 Here, since the heat-generating current  $i_B$  is set at a value higher than the comparative reference current  $i_A$ , a deviation would be created therebetween during no developing of frost or dew if compared as they are. To meet the two values with each other, in this embodiment, the comparative reference current  $i_A$  is amplified by an amplifier 778, when detecting the comparative reference current, up to a level equal to the detection value by the heat-generating current.

20 As is apparent from FIG. 7, the output of the thermosensitive resistor 750 is amplified by the amplifier 778, and then the amplified output is held for a predetermined period by a holding circuit 780 succeeding to the amplifier 778.

25 In this embodiment, this signal is held when the comparative reference current  $i_A$  is supplied to the thermosensitive resistor 750, and the angle of amplification of the amplifier 778 can be given by the following equation:

$$\alpha = i_B R_0 / i_A R_0 = i_B / i_A$$

30 Then the output of the amplifier 778 enters the holding circuit 780. Since two current values are sequentially impressed to this holding circuit 780 as described above, the voltages created at the thermosensitive resistor 750 by the two current values cannot be compared. For instance, the voltage created at the amplifier 778, when the current value  $i_A$  is supplied, is temporarily held so that the 35 comparator circuit 762 can compare this voltage with the voltage created at the thermosensitive resistor 750 by the supply of the current value  $i_B$  after a predetermined period of time.

40 The comparator circuit 762 compares a differential temperature created when the currents  $i_A$ ,  $i_B$  are supplied to the thermosensitive resistor 750. On the other hand, to make a judgment on the 45 developing of frost only, a freezing level detector circuit 766 parallel to the comparator circuit 762 discriminates whether the ambient temperature  $T_a$

of the thermosensitive resistor 750 is below  $0^{\circ}\text{C}$ , which causes frost to develop.

To the output circuit 770 serving as the output means for the constant-current variable circuit 776, the amplifier 778 and the arithmetic circuit 760, the timing signal generator circuit 782 supplies a signal to alternately change over the current values between  $i_A$ ,  $i_B$  to be supplied to the thermosensitive resistor 750, another signal to do that change-over in response to the last-named signal, and still another signal to do the output control, each signal at a predetermined period.

If the temperature increase is below a reference value, a discriminator 768 judges it as a sign of the developing of frost or dew, based on the output of the comparator circuit 762. To detect the developing of frost only, it requires an additional condition that an ambient temperature  $T_0$  is below  $0^{\circ}\text{C}$ .

FIG. 8 shows the perspective appearance around the thermosensitive resistor 750 in the practical sensor of FIG. 7. In FIG. 8, the thermosensitive resistor 750 is carried on a distal end of a shaft 752 extending through a side wall of a base 746 in the form of an angled or hook-shaped plate.

With no frost or dew around, as shown in FIG. 9, the thermosensitive resistor 750 is located in air. With frost or dew around, as shown in FIG. 10, the surface of the thermosensitive resistor 750 is covered with frost or dew.

The operation of the sensor of FIG. 7 (third embodiment) will now be described in greater detail with reference to FIG. 11 showing a practical circuit.

In FIG. 11, to the thermosensitive resistor 750, a comparative reference current  $i_A$  and a heat-generating current  $i_B$  are alternately supplied at chronologically different timings from the constant-current variable circuit 776 which is composed of the transistors  $Q_1$ ,  $Q_2$ .

To make a change-over on the constant-current variable circuit 776, the sensor is equipped with a timing circuit 782. In the illustrated embodiment, the timing circuit 782 includes an oscillator 784 and a gate 786; the respective supply timings of the two current values  $i_A$ ,  $i_B$  are alternately changed over in an oscillation period of the oscillator 784.

The oscillator 784 supplies an oscillation output from the gate 786 to the collector of each of the transistors  $Q_1$ ,  $Q_2$  via a resistance 788. When the output of the oscillator 784 is "L" level, the current flowing to the collector of the transistor  $Q_2$  via the resistance 788 increases. At that moment, since the transistors  $Q_1$ ,  $Q_2$  jointly constitute a so-called current mirror, the initial current value  $i_A$  increases to reach the heat-generating current  $i_B$  as the current  $i_A$  flows through the collector of the transistor  $Q_2$ .

5 The output side of the thermosensitive resistor 750 is connected to the negative input side of the comparator circuit 762, as described above; when the comparative reference current  $i_A$  is supplied to the thermosensitive resistor 750, then its output is supplied to the amplifier 778.

10 The amplifier 778 is composed of an amplifier circuit 790 and a switch 792 disposed immediately upstream of the amplifier circuit 790. When the output of the oscillator 784 is "L" level, the timing circuit 782 issues a change-over signal to open the switch 792.

15 Accordingly, the amplifier 778 can fetch the output of the thermosensitive resistor 750 only when the comparative reference current  $i_A$  is supplied to the thermosensitive resistor 750.

20 The output of the amplifier 778 is supplied to the holding circuit 780, and the output of the holding circuit is supplied to the positive input terminal of the comparator 762.

25 Thus the comparator 762 makes a delay, by the holding circuit 780, of one of the outputs of the thermosensitive resistor 750, when the comparative reference current  $i_A$  and the heat-generating current  $i_B$  are supplied to the thermosensitive resistor 750 at the chronologically different timings, to meet the respective timings for comparison.

30 In the amplifier 778, its amplification constant is set such that the signal values to be supplied to the comparator 762 are identical when no frost or dew exists around the thermosensitive resistor 750. Consequently the output of the comparator 762 is 0 (zero) during no developing of frost or dew.

35 On the contrary, when frost or dew develops over the surface of the thermosensitive resistor 750, the negative input value of the comparator circuit 762 descends. A signal corresponding to the difference in temperature increase due to the heat-generation is supplied from a first comparator 794 to a second comparator 796 where the output value of the first comparator 794 is compared with a reference value. Then from the second comparator 796, a frost-and-dew signal is outputted when the difference in temperature increase due to heat radiation is over a predetermined value.

40 Thus in this embodiment, the sensor is also equipped with a freezing level detector circuit 766 to obtain a signal when frost has developed over the thermosensitive resistor 750. In the freezing level detector circuit 766, the output of the holding circuit 780, namely, the output of the thermosensitive resistor 750 during supplying the comparative reference current  $i_A$  is compared with the reference value. When the ambient temperature (thermistor) descends below  $0^{\circ}\text{C}$ , then the frost signal is outputted.

45 Further, these two detection signals take their AND output by the discriminator circuit 768 includ-

ing the gate 798, and are then supplied to a non-illustrated processing circuit via the output circuit 770.

Here, during the comparative reference current  $i_A$  is being supplied to the thermosensitive resistor 750, the negative input value of the first comparator 794 is lower than the positive input value by  $1/\alpha$ . This difference is outputted to the first comparator 796, which might cause an error frost-and-dew signal.

A switch 800 is connected to the output side of the discriminator 768. To this switch 800, a timing signal is supplied from the oscillator 784 in the timing circuit 782 via a gate 802 built in the timing circuit 782. By releasing the switch 800 when the comparative reference current  $i_A$  flows to the thermosensitive resistor 750, it is possible to avoid such a misoperation.

Connected to the downstream side of the switch 800 are two transistors  $Q_3$ ,  $Q_4$ , which constitute, jointly with the switch 8000, the output circuit 770. Vcc is connected to the collector and base of each of the two transistors  $Q_3$ ,  $Q_4$ . These transistors  $Q_3$ ,  $Q_4$  serve to amplify the output of the discriminator 768 and deliver this amplified output as a frost-and-dew notifying signal to a subsequent processing circuit.

In this illustrated embodiment, the principles of this invention is applied for the purpose of detecting frost only. Alternatively, by omitting or modifying each of the foregoing threshold levels, it is possible to detect both frost and dew, or only dew.

According to this embodiment, partly since the thermosensitive resistor used as a frost and dew detecting means is hardly subjected to the exterior force or vibration, and partly since the thermosensitive resistor is inexpensive and small-sized and has an excellent mechanical strength, it is possible to detect the developing of frost or dew with very high reliability.

FIG. 12 shows a fourth embodiment, in which an output port signal of a  $\mu$ -CPU 906, instead of the oscillation circuit, is used to instruct the constant-current variable circuit 876 to change over the current to be supplied to the thermosensitive resistor 850. The detected temperature signal from a thermosensitive resistor 850 is digitalized by an A/D converter 904 and is then processed in the  $\mu$ -CPU 906. The result of arithmetical operation in the  $\mu$ -CPU 906 is outputted as a frost-and-dew signal from an output circuit 870.

Apart from the arithmetical operation of the detection signals, this embodiment is identical in the basic principle of frost and dew detection with the third embodiment, giving the similar result.

To sum up the foregoing description, according to the first and second embodiments, partly because a pair of thermosensitive resistors is used as

a frost and dew detecting means, and partly because the change of a differential temperature between the thermosensitive resistors is used as a parameter for the arithmetical operation, occurrence of misdetection due to any outside force or vibration can be reduced to a minimum, thus guaranteeing an inexpensive frost and dew sensor which offers a very reliable performance and has an adequate mechanical strength.

According to the third and fourth embodiments, partly since a heat-generating current and a comparative reference current are alternately supplied to a single thermosensitive resistor such as a thermistor to create a differential temperature, and partly since the developing of frost or dew is detected in terms of the reduced differential temperature due to the action of heat conducting when frost or dew has developed over the surface of the thermosensitive resistor, it is possible to achieve an improved frost and dew sensor which is small-sized, durable and inexpensive and offers an reliable detection performance. Further, sensible detection of frost and dew can be achieved without causing any misoperation due to the outside force or vibration.

In a frost and dew sensor composed of two thermosensitive resistors, a power source and an arithmetic circuit, frost or dew is detected from the change of a differential temperature between the two thermosensitive resistors as two different currents from the power source are supplied to the respective thermosensitive resistors. In an alternative form, the sensor has a single thermosensitive resistor, which is energized as two different currents are alternately supplied from the power source so that frost or dew is detected by comparison of the time-lags between the two outputs from the thermosensitive resistor.

#### 40 Claims

1. A frost and dew sensor comprising:
  - (a) a pair of thermosensitive resistors disposed adjacent to each other, each of said thermosensitive resistors being capable of generating heat by itself due to a given current supplied thereto, each said thermosensitive resistor having a resistance varying according to the change of temperature of each said thermosensitive resistor;
  - (b) a power source for creating a differential temperature between said thermosensitive resistors, said power source including a heat-generating current source for supplying a heat-generating current to one of said thermosensitive resistors, and a comparative reference current source for supplying a comparative reference current to the other thermosensitive resistor so as to cause a temperature

increase of said other thermosensitive resistor to only a negligible extent with respect to the temperature increase of said one thermosensitive resistor due to the heat-generating current;

(c) An arithmetic circuit for fetching a temperature at a respective one of said pair of thermosensitive resistors as an output voltage corresponding to the resistance of said respective thermosensitive resistor and for generating a frost-and-dew signal according to a difference in output voltage between said pair of thermosensitive resistors, whereby the frost-and-dew signal is issued as presumed that said thermosensitive resistor are covered with frost or dew when the temperature of said one thermosensitive resistor, to which the heat-generating current is supplied, is lowered.

2. A frost and dew sensor according to claim 1, wherein said arithmetic circuit includes a comparator circuit for detecting a difference between the respective output signals of said thermosensitive resistors and for comparing the difference with a reference value.

3. A frost and dew sensor according to claim 2, wherein said comparator circuit includes:  
a first comparator for comparing the respective output signals of said thermosensitive resistors with one another to detect the difference between the two output signals; and  
a second comparator for comparing the output signal of said first comparator with a reference value.

4. A frost and dew sensor according to claim 2, wherein said arithmetic circuit includes a freezing level detector circuit for comparing the output voltage of said other thermosensitive resistor corresponding to the comparative reference current with a predetermined freezing level reference value to detect whether an ambient temperature of said other thermosensitive resistor is below the freezing point.

5. A frost and dew sensor according to claim 4, wherein said arithmetic circuit includes a discriminator for comparing the output signal of said comparator circuit with the output signal of said freezing level detector circuit to discriminate whether said thermosensitive resistors are covered with frost, when the ambient temperature of said thermosensitive resistors is below the freezing point.

6. A frost and dew sensor according to claim 5, wherein said arithmetic circuit includes an output circuit for amplifying the output of said discriminator to output the amplified output.

7. A frost and dew sensor according to claim 2, wherein said arithmetic circuit includes:  
a freezing level detector circuit for comparing the output voltage of said other thermosensitive resistor corresponding to the comparative reference current with a predetermined freezing level reference

value to detect whether an ambient temperature of said other thermosensitive resistor is below the freezing point;

5 a discriminator for comparing the output signal of said comparator circuit with the output signal of said freezing level detector circuit to discriminate whether said thermosensitive resistors are covered with frost, when the ambient temperature of said thermosensitive resistors are below the freezing point; and  
an output circuit for amplifying the output of said discriminator to output the amplified output.

10 8. A frost and dew sensor according to claim 1, further including a pair of shafts carrying thereon said respective thermosensitive resistors, and a base supporting said shafts.

15 9. A frost and dew sensor according to claim 1, wherein said arithmetic circuit includes:  
an A/D converter for converting the output voltage of each said thermosensitive resistor into digital data;  
a μ-CPU for performing a predetermined arithmetical operation with respect to the digital data, outputted from said A/D converter, to find a differential temperature at said thermosensitive resistors; and  
20 an output circuit for generating and outputting a frost-and-dew signal according to the arithmetic result of said μ-CPU.

25 10. A frost and dew sensor according to claim 1, wherein each of said thermosensitive resistors is a thermistor.

30 11. A frost and dew sensor according to claim 1, wherein each of said thermosensitive resistors is a resistor formed from platinum or nickel.

35 12. A frost and dew sensor according to claim 7, wherein each of said thermosensitive resistors is a thermistor.

40 13. A frost and dew sensor comprising:  
(a) a thermosensitive resistor capable of generating heat by itself due to a given current supplied thereto, said thermosensitive resistor having a resistance varying according to the change of temperature of said thermosensitive resistor;

45 (b) a power source for changing the temperature of said thermosensitive resistor periodically, said power source including a variable constant-current source for alternately supplying a heat-generating current and a comparative reference current to said thermosensitive resistor, said comparative reference current being such that it causes a temperature increase of said thermosensitive resistor to only a negligible extent with respect to the temperature increase due to the heat-generating current; and

50 55 (c) an arithmetic circuit for fetching a temperature of said thermosensitive resistor as an output voltage according to a resistance corresponding to the temperature and for generating a frost-

and-dew signal according to a difference between the output voltage during the heat-generating current is being supplied to said thermosensitive resistor and the output voltage during the comparative reference current is being supplied to said thermosensitive resistor, whereby the frost-and-dew signal is issued as presumed that said thermosensitive resistor is covered with frost or dew when a differential temperature of said thermosensitive resistor in such two durations is lowered.

14. A frost and dew sensor according to claim 13, wherein said arithmetic circuit includes: an amplifier for amplifying the output voltage of said thermosensitive resistor, during the comparative reference current is being supplied thereto, at a rate corresponding to a ratio of the heat-generating voltage to the comparative reference current to output the amplified output voltage; a holding circuit for holding the output of said amplifier to output the same output with a delay for the duration the comparative reference current is being supplied to said thermosensitive resistor; and a comparator circuit for first comparing the output of said holding circuit with the output voltage of said thermosensitive resistor, during the heat-generating current is being supplied, to find a differential temperature of said thermosensitive resistor between the temperature during the comparative reference current is being supplied and that during the heat-generating current is being supplied, and for secondly comparing the differential temperature with a predetermined reference value.

15. A frost and dew sensor according to claim 13, wherein said arithmetic circuit includes: an A/D converter for converting the output voltage of each said thermosensitive resistor into digital data; a  $\mu$ -CPU for performing a predetermined arithmetical operation with respect to the digital data, outputted from said A/D converter, to find a differential temperature at said thermosensitive resistors; and an output circuit for generating and outputting a frost-and-dew signal according to the arithmetic result of said  $\mu$ -CPU.

16. A frost and dew sensor according to claim 14, wherein said comparator circuit includes: a first comparator for comparing the output signal of said thermosensitive resistor, during the heat-generating current is being supplied, with the output of said holding circuit to find the difference between the two outputs; and a second comparator for comparing the output signal of said first comparator with a reference value.

17. A frost and dew sensor according to claim 16, wherein said arithmetic circuit includes a freezing level detector circuit for comparing the output current of said thermosensitive resistor correspond-

ing to the comparative reference current with a predetermined freezing level reference value to detect whether an ambient temperature of said thermosensitive resistor is below the freezing point.

5 18. A frost and dew sensor according to claim 17, wherein said arithmetic circuit includes a discriminator for comparing the output signal of said comparator circuit with the output signal of said freezing level detector circuit to discriminate whether said thermosensitive resistor is covered with frost, when the ambient temperature of said thermosensitive resistor is below the freezing point.

10 19. A frost and dew sensor according to claim 18, wherein said arithmetic circuit includes an amplifier for amplifying the output of said discriminator to output the amplified output; said power source including an oscillator for producing an alternate timing to alternate the output of said variable constant-current source between the comparative reference current and the heat-generating current, said oscillator including a timing circuit for supplying a control signal to said amplifier according to the alternate timing produced by said oscillator and also for supplying the same control signal to said output circuit according to the same alternate timing; said amplifier circuit including a switch adapted to be energized and deenergized by said timing circuit in such a manner that the output current of said thermosensitive resistor is inputted only during the comparative reference current is being supplied to said thermosensitive resistor; and said output circuit including another switch adapted to be energized and deenergized by said timing circuit in such a manner that the output of the frost-and-dew signal to the exterior is prohibited during the comparative reference current is being supplied to said thermosensitive resistor.

20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 1225 1230 1235 1240 1245 1250 1255 1260 1265 1270 1275 1280 1285 1290 1295 1300 1305 1310 1315 1320 1325 1330 1335 1340 1345 1350 1355 1360 1365 1370 1375 1380 1385 1390 1395 1400 1405 1410 1415 1420 1425 1430 1435 1440 1445 1450 1455 1460 1465 1470 1475 1480 1485 1490 1495 1500 1505 1510 1515 1520 1525 1530 1535 1540 1545 1550 1555 1560 1565 1570 1575 1580 1585 1590 1595 1600 1605 1610 1615 1620 1625 1630 1635 1640 1645 1650 1655 1660 1665 1670 1675 1680 1685 1690 1695 1700 1705 1710 1715 1720 1725 1730 1735 1740 1745 1750 1755 1760 1765 1770 1775 1780 1785 1790 1795 1800 1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130 2135 2140 2145 2150 2155 2160 2165 2170 2175 2180 2185 2190 2195 2200 2205 2210 2215 2220 2225 2230 2235 2240 2245 2250 2255 2260 2265 2270 2275 2280 2285 2290 2295 2300 2305 2310 2315 2320 2325 2330 2335 2340 2345 2350 2355 2360 2365 2370 2375 2380 2385 2390 2395 2400 2405 2410 2415 2420 2425 2430 2435 2440 2445 2450 2455 2460 2465 2470 2475 2480 2485 2490 2495 2500 2505 2510 2515 2520 2525 2530 2535 2540 2545 2550 2555 2560 2565 2570 2575 2580 2585 2590 2595 2600 2605 2610 2615 2620 2625 2630 2635 2640 2645 2650 2655 2660 2665 2670 2675 2680 2685 2690 2695 2700 2705 2710 2715 2720 2725 2730 2735 2740 2745 2750 2755 2760 2765 2770 2775 2780 2785 2790 2795 2800 2805 2810 2815 2820 2825 2830 2835 2840 2845 2850 2855 2860 2865 2870 2875 2880 2885 2890 2895 2900 2905 2910 2915 2920 2925 2930 2935 2940 2945 2950 2955 2960 2965 2970 2975 2980 2985 2990 2995 3000 3005 3010 3015 3020 3025 3030 3035 3040 3045 3050 3055 3060 3065 3070 3075 3080 3085 3090 3095 3100 3105 3110 3115 3120 3125 3130 3135 3140 3145 3150 3155 3160 3165 3170 3175 3180 3185 3190 3195 3200 3205 3210 3215 3220 3225 3230 3235 3240 3245 3250 3255 3260 3265 3270 3275 3280 3285 3290 3295 3300 3305 3310 3315 3320 3325 3330 3335 3340 3345 3350 3355 3360 3365 3370 3375 3380 3385 3390 3395 3400 3405 3410 3415 3420 3425 3430 3435 3440 3445 3450 3455 3460 3465 3470 3475 3480 3485 3490 3495 3500 3505 3510 3515 3520 3525 3530 3535 3540 3545 3550 3555 3560 3565 3570 3575 3580 3585 3590 3595 3600 3605 3610 3615 3620 3625 3630 3635 3640 3645 3650 3655 3660 3665 3670 3675 3680 3685 3690 3695 3700 3705 3710 3715 3720 3725 3730 3735 3740 3745 3750 3755 3760 3765 3770 3775 3780 3785 3790 3795 3800 3805 3810 3815 3820 3825 3830 3835 3840 3845 3850 3855 3860 3865 3870 3875 3880 3885 3890 3895 3900 3905 3910 3915 3920 3925 3930 3935 3940 3945 3950 3955 3960 3965 3970 3975 3980 3985 3990 3995 4000 4005 4010 4015 4020 4025 4030 4035 4040 4045 4050 4055 4060 4065 4070 4075 4080 4085 4090 4095 4100 4105 4110 4115 4120 4125 4130 4135 4140 4145 4150 4155 4160 4165 4170 4175 4180 4185 4190 4195 4200 4205 4210 4215 4220 4225 4230 4235 4240 4245 4250 4255 4260 4265 4270 4275 4280 4285 4290 4295 4300 4305 4310 4315 4320 4325 4330 4335 4340 4345 4350 4355 4360 4365 4370 4375 4380 4385 4390 4395 4400 4405 4410 4415 4420 4425 4430 4435 4440 4445 4450 4455 4460 4465 4470 4475 4480 4485 4490 4495 4500 4505 4510 4515 4520 4525 4530 4535 4540 4545 4550 4555 4560 4565 4570 4575 4580 4585 4590 4595 4600 4605 4610 4615 4620 4625 4630 4635 4640 4645 4650 4655 4660 4665 4670 4675 4680 4685 4690 4695 4700 4705 4710 4715 4720 4725 4730 4735 4740 4745 4750 4755 4760 4765 4770 4775 4780 4785 4790 4795 4800 4805 4810 4815 4820 4825 4830 4835 4840 4845 4850 4855 4860 4865 4870 4875 4880 4885 4890 4895 4900 4905 4910 4915 4920 4925 4930 4935 4940 4945 4950 4955 4960 4965 4970 4975 4980 4985 4990 4995 5000 5005 5010 5015 5020 5025 5030 5035 5040 5045 5050 5055 5060 5065 5070 5075 5080 5085 5090 5095 5100 5105 5110 5115 5120 5125 5130 5135 5140 5145 5150 5155 5160 5165 5170 5175 5180 5185 5190 5195 5200 5205 5210 5215 5220 5225 5230 5235 5240 5245 5250 5255 5260 5265 5270 5275 5280 5285 5290 5295 5300 5305 5310 5315 5320 5325 5330 5335 5340 5345 5350 5355 5360 5365 5370 5375 5380 5385 5390 5395 5400 5405 5410 5415 5420 5425 5430 5435 5440 5445 5450 5455 5460 5465 5470 5475 5480 5485 5490 5495 5500 5505 5510 5515 5520 5525 5530 5535 5540 5545 5550 5555 5560 5565 5570 5575 5580 5585 5590 5595 5600 5605 5610 5615 5620 5625 5630 5635 5640 5645 5650 5655 5660 5665 5670 5675 5680 5685 5690 5695 5700 5705 5710 5715 5720 5725 5730 5735 5740 5745 5750 5755 5760 5765 5770 5775 5780 5785 5790 5795 5800 5805 5810 5815 5820 5825 5830 5835 5840 5845 5850 5855 5860 5865 5870 5875 5880 5885 5890 5895 5900 5905 5910 5915 5920 5925 5930 5935 5940 5945 5950 5955 5960 5965 5970 5975 5980 5985 5990 5995 6000 6005 6010 6015 6020 6025 6030 6035 6040 6045 6050 6055 6060 6065 6070 6075 6080 6085 6090 6095 6100 6105 6110 6115 6120 6125 6130 6135 6140 6145 6150 6155 6160 6165 6170 6175 6180 6185 6190 6195 6200 6205 6210 6215 6220 6225 6230 6235 6240 6245 6250 6255 6260 6265 6270 6275 6280 6285 6290 6295 6300 6305 6310 6315 6320 6325 6330 6335 6340 6345 6350 6355 6360 6365 6370 6375 6380 6385 6390 6395 6400 6405 6410 6415 6420 6425 6430 6435 6440 6445 6450 6455 6460 6465 6470 6475 6480 6485 6490 6495 6500 6505 6510 6515 6520 6525 6530 6535 6540 6545 6550 6555 6560 6565 6570 6575 6580 6585 6590 6595 6600 6605 6610 6615 6620 6625 6630 6635 6640 6645 6650 6655 6660 6665 6670 6675 6680 6685 6690 6695 6700 6705 6710 6715 6720 6725 6730 6735 6740 6745 6750 6755 6760 6765 6770 6775 6780 6785 6790 6795 6800 6805 6810 6815 6820 6825 6830 6835 6840 6845 6850 6855 6860 6865 6870 6875 6880 6885 6890 6895 6900 6905 6910 6915 6920 6925 6930 6935 6940 6945 6950 6955 6960 6965 6970 6975 6980 6985 6990 6995 7000 7005 7010 7015 7020 7025 7030 7035 7040 7045 7050 7055 7060 7065 7070 7075 7080 7085 7090 7095 7100 7105 7110 7115 7120 7125 7130 7135 7140 7145 7150 7155 7160 7165 7170 7175 7180 7185 7190 7195 7200 7205 7210 7215 7220 7225 7230 7235 7240 7245 7250 7255 7260 7265 7270 7275 7280 7285 7290 7295 7300 7305 7310 7315 7320 7325 7330 7335 7340 7345 7350 7355 7360 7365 7370 7375 7380 7385 7390 7395 7400 7405 7410 7415 7420 7425 7430 7435 7440 7445 7450 7455 7460 7465 7470 7475 7480 7485 7490 7495 7500 7505 7510 7515 7520 7525 7530 7535 7540 7545 7550 7555 7560 7565 7570 7575 7580 7585 7590 7595 7600 7605 7610 7615 7620 7625 7630 7635 7640 7645 7650 7655 7660 7665 7670 7675 7680 7685 7690 7695 7700 7705 7710 7715 7720 7725 7730 7735 7740 7745 7750 7755 7760 7765 7770 7775 7780 7785 7790 7795 7800 7805 7810 7815 7820 7825 7830 7835 7840 7845 7850 7855 7860 7865 7870 7875 7880 7885 7890 7895 7900 7905 7910 7915 7920 7925 7930 7935 7940 7945 7950 7955 7960 7965 7970 7975 7980 7985 7990 7995 8000 8005 8010 8015 8020 8025 8030 8035 8040 8045 8050 8055 8060 8065 8070 8075 8080 8085 8090 8095 8100 8105 8110 8115 8120 8125 8130 8135 8140 8145 8150 8155 8160 8165 8170 8175 8180 8185 8190 8195 8200 8205 8210 8215 8220 8225 8230 8235 8240 8245 8250 8255 8260 8265 8270 8275 8280 8285 8290 8295 8300 8305 8310 8315 8320 8325 8330 8335 8340 8345 8350 8355 8360 8365 8370 8375 8380 8385 8390 8395 8400 8405 8410 8415 8420 8425 8430 8435 8440 8445 8450 8455 8460 8465 8470 8475 8480 8485 8490 8495 8500 8505 8510 8515 8520 8525 8530 8535 8540 8545 8550 8555 8560 8565 8570 8575 8580 8585 8590 8595 8600 8605 8610 8615 8620 8625 8630 8635 8640 8645 8650 8655 8660 8665 8670 8675 8680 8685 8690 8695 8700 8705 8710 8715 8720 8725 8730 8735 8740 8745 8750 8755 8760 8765 8770 8775 8780 8785 8790 8795 8800 8805 8810 8815 8820 8825 8830 8835 8840 8845 8850 8855 8860 8865 8870 8875 8880 8885 8890 8895 8900 8905 8910 8915 8920 8925 8930 8935 8940 8945 8950 8955 8960 8965 8970 8975 8980 8985 8990 8995 9000 9005 9010 9015 9020 9025 9030 9035 9040 9045 9050 9055 9060 9065 9070 9075 9080 9085 9090 9095 9100 9105 9110 9115 9120 9125 9130 9135 9140 9145 9150 9155 9160 9165 9170 9175 9180 9185 9190 9195 9200 9205 9210 9215 9220 9225 9230 9235 9240 9245 9250 9255 9260 9265 9270 9275 9280 9285 9290 9295 9300 9305 9310 9315 9320 9325 9330 9335 9340 9345 9350 9355 9360 9365 9370 9375 9380 9385 9390 9395 9400 9405 9410 9415 9420 9425 9430 9435 9440 9445 9450 9455 9460 9465 9470 9475 9480 9485 9490 9495 9500 9505 9510 9515 9520 9525 9530 9535 9540 9545 9550 9555 9560 9565 9570 9575 9580 9585 9590 9595 9600 9605 9610 9615 9620 9625 9630 9635 9640 9645 9650 9655 9660 9665 9670 9675 9680 9685 9690 9695 9700 9705 9710 9715 9720 9725 9730 9735 9740 9745 9750 9755 9760 9765 9770 9775 9780 9785 9790 9795 9800 9805 9810 9815 9820 9825 9830 9835 9840 9845 9850 9855 9860 9865 9870 9875 9880 9885 9890 9895 9900 9905 9910 9915 9920 9925 9930 9935 9940 9945 9950 9955 9960 9965 9970 9975 9980 9985 9990 9995 10000 10005 10010 10015 10020 10025 10030 10035 10040 10045 10050 10055 10060 10065 10070 10075 10080 10085 10090 10095 10100 10105 10110 10115 10120 10125 10130 10135 10140 10145 10150 10155 10160 10165 10170 10175 10180 10185 10190 10195 10200 10205 10210 10215 10220 10225 10230 10235 10240 10245 10250 10255 10260 10265 10270 10275 10280 10285 10290 10295 10300 10305 10310 10315 10320 10325 10330 10335 10340 10345 1

FIG. 1

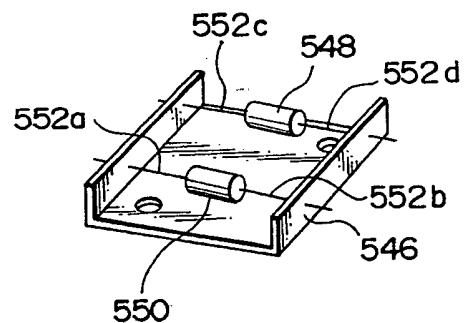


FIG. 2

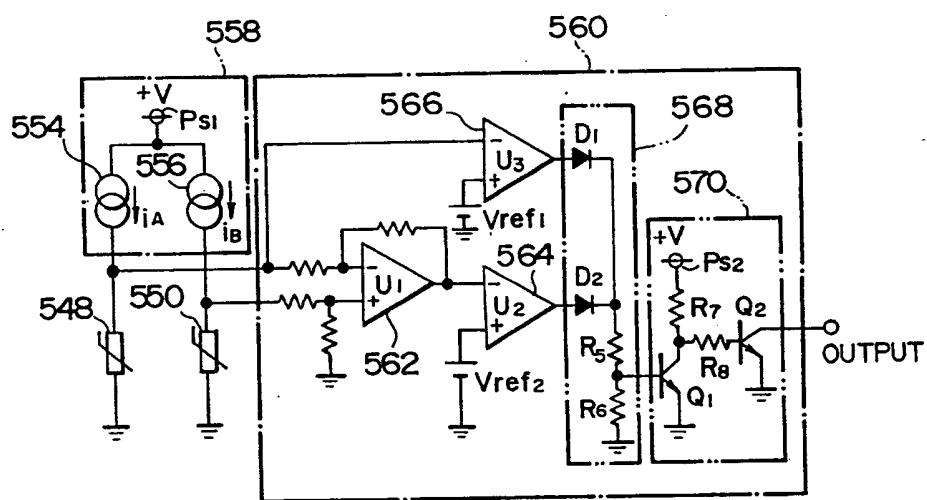


FIG. 3

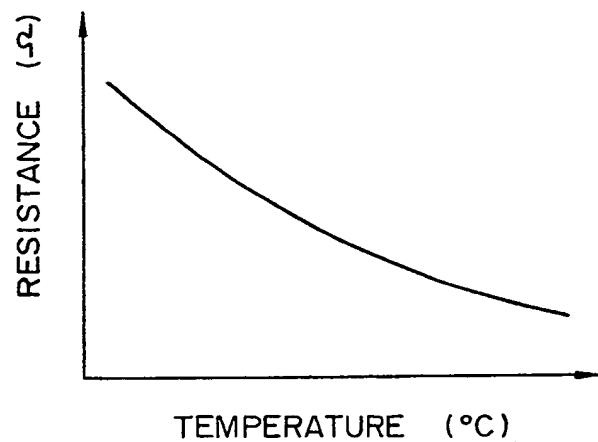


FIG. 4

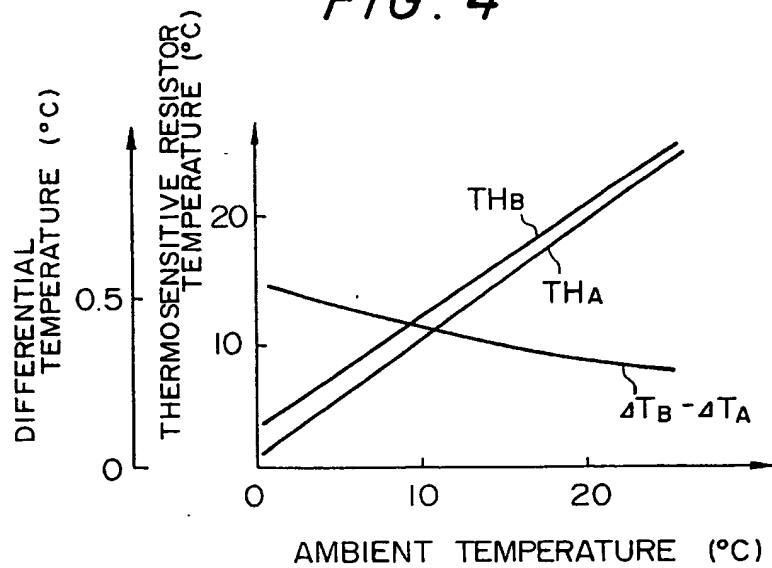


FIG. 5

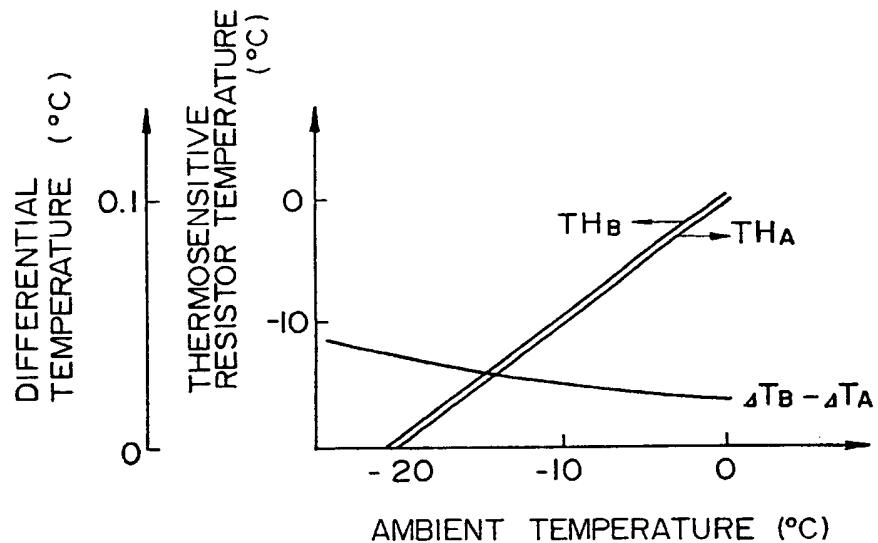


FIG. 6

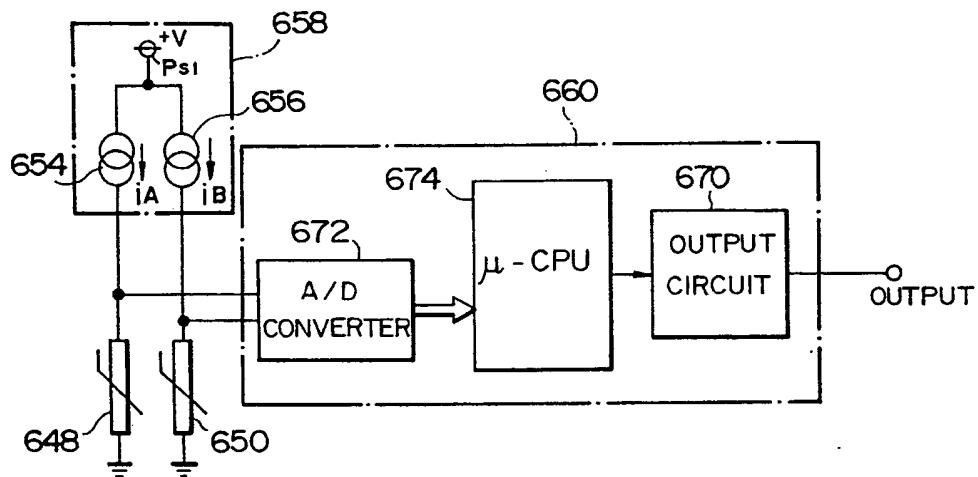


FIG. 7

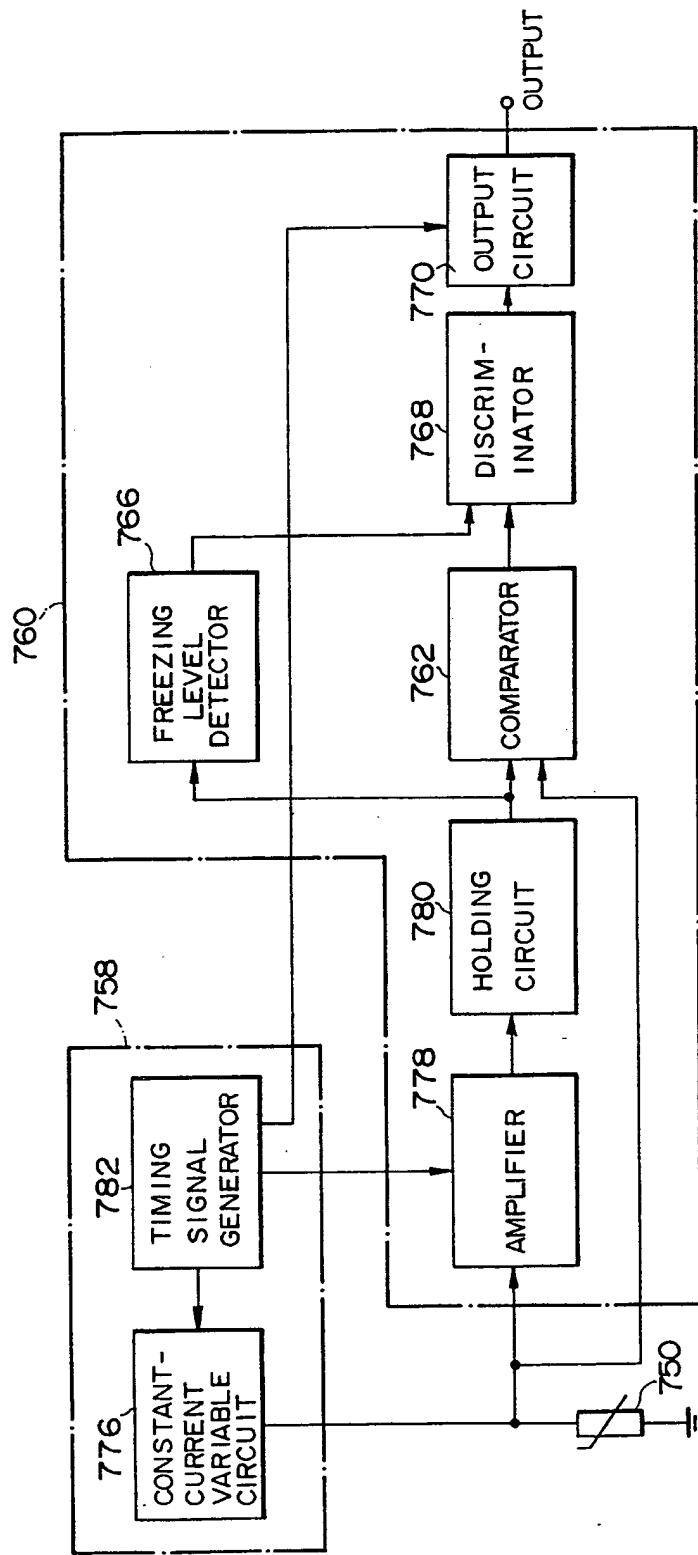


FIG. 8

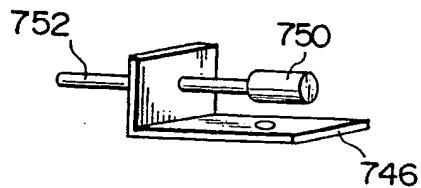


FIG. 9

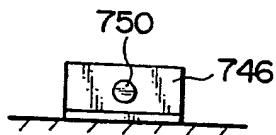


FIG. 10

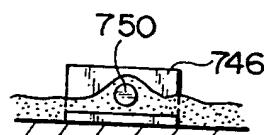
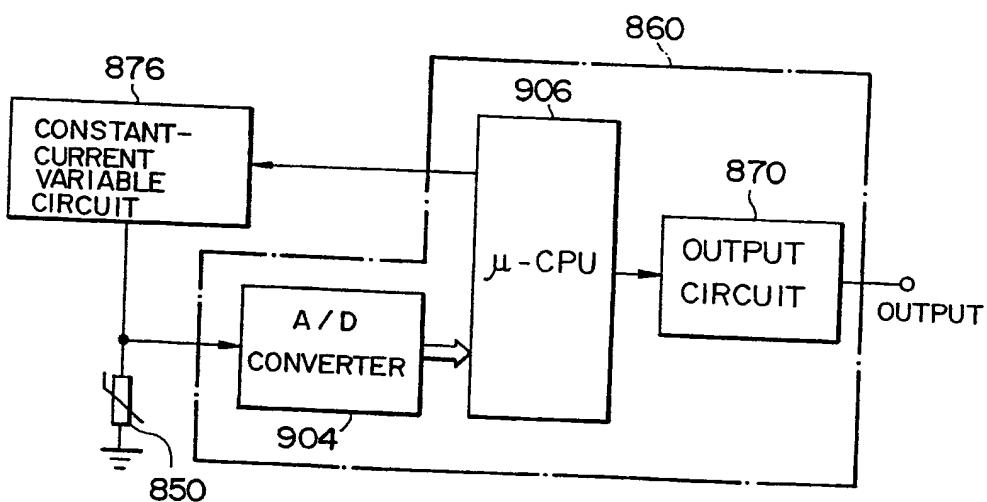


FIG. 12



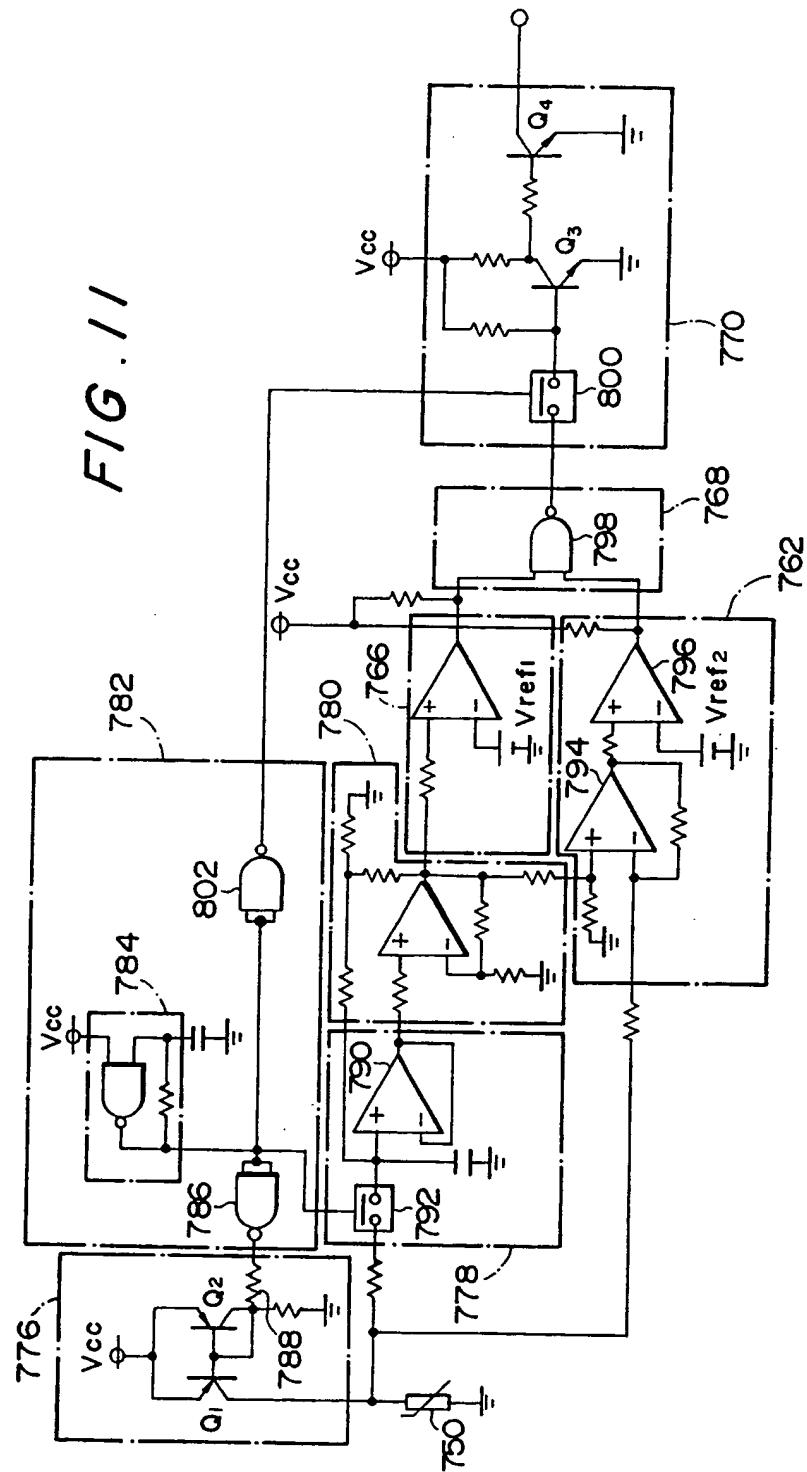


FIG. 13

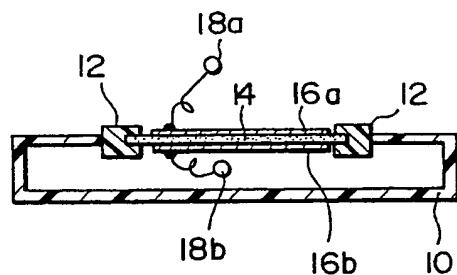


FIG. 14

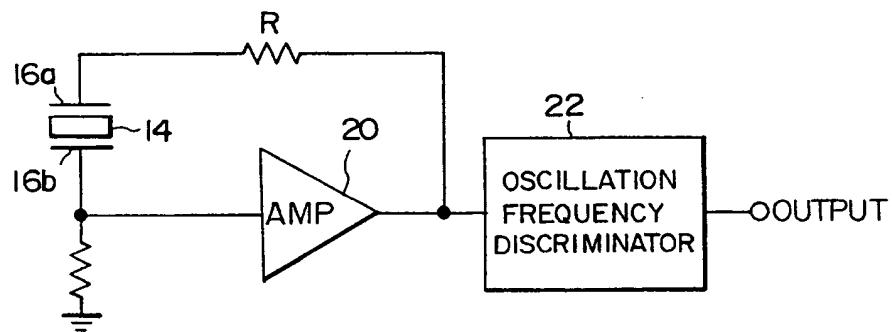


FIG. 15

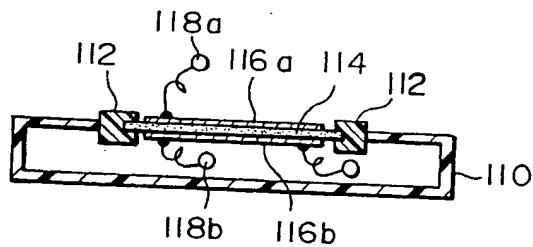


FIG. 16

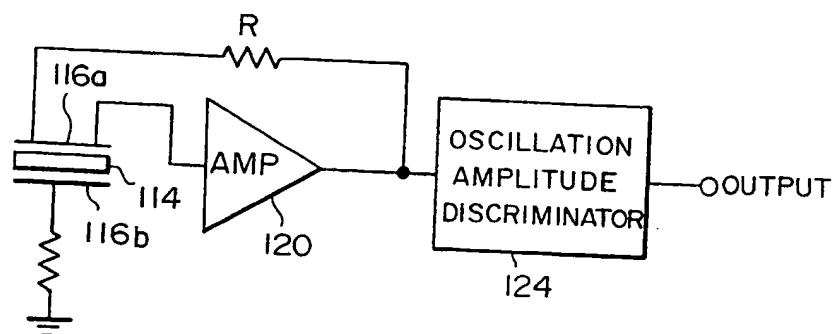


FIG. 17

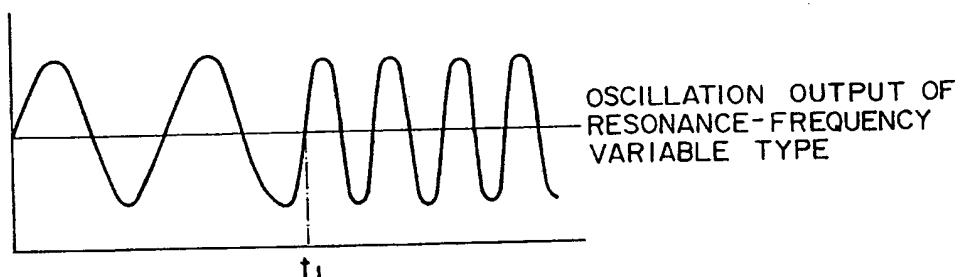


FIG. 18

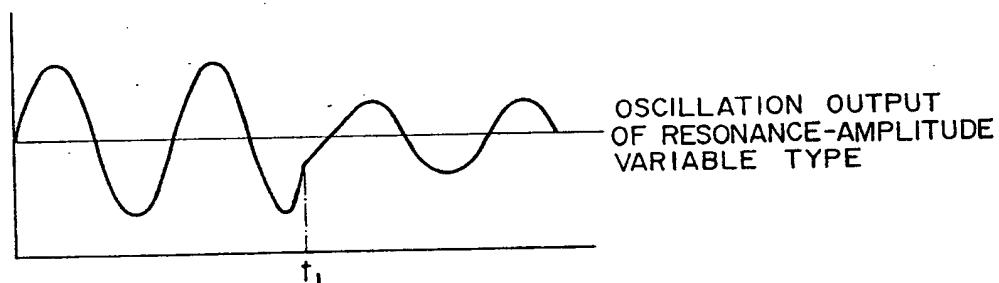


FIG. 19

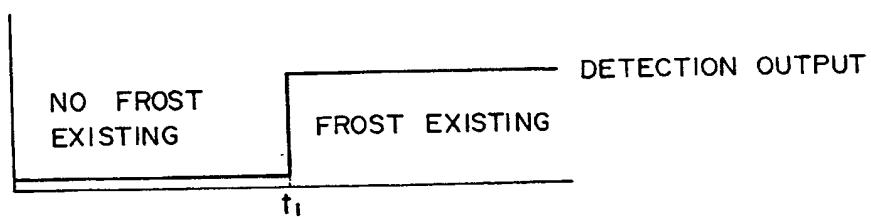


FIG. 20

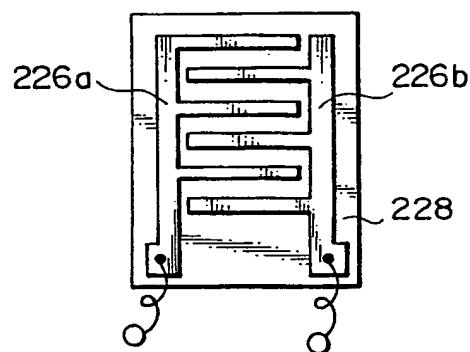


FIG. 21

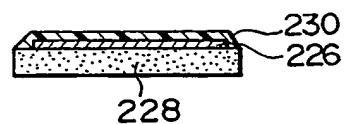


FIG. 22

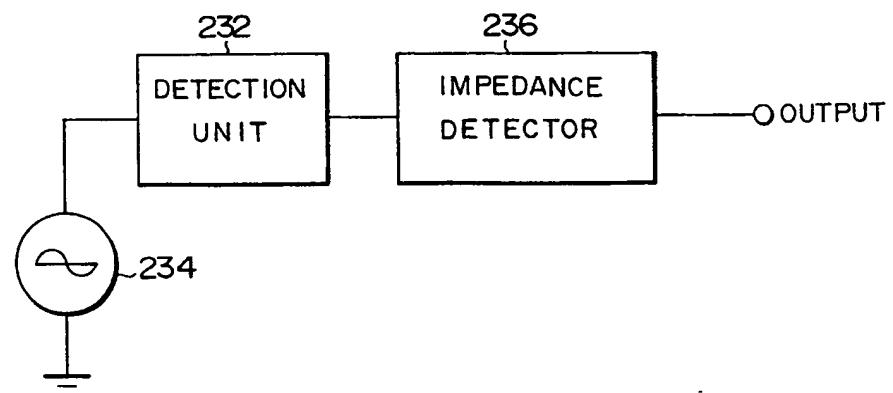


FIG. 23

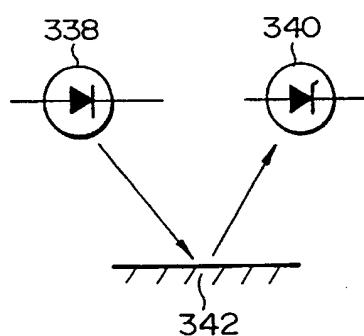


FIG. 24

